# HAEMOSTATIC SPRAYS AND COMPOSITIONS

## FIELD OF THE INVENTION

The present invention is directed to a powder delivery system containing a composition comprising gelatine or collagen powder having a mean particle size of at least 10 μm. The gelatine or collagen powder is typically in dry form, i.e. no liquid components and/or propellants are added to the composition. The present invention is also directed to an improved powder delivery system which contains a protective structure, such as a skirt, located close to the orifice of the delivery system. In a further aspect, the present invention is directed to gelatine- or collagen-based compositions useful in haemostatic applications.

## BACKGROUND OF THE INVENTION

WO 01/28603 relates to an injectable formulation for delivery of a composition comprising an osteogenic protein and a haemostatic gelatine foam paste as well as to a method of making a haemostatic gelatine foam paste suitable for injecting osteogenic protein, the method comprising hydration of Gelfoam® powder with glutamic acid buffer.

US 5,394,886 relates to a skin biopsy plug wherein the plug is a porous sponge made from gelatine material, which is implanted into a wound, swells, absorbs blood, and is completely absorbed in the patient. It relates to a combination of the punch (the blade for excising skin) and the plug. The plug used is the commercially available Gelfoam®.

GelFoam® is a commercially available product providing powdered gelatine for application to bleeding surfaces as a haemostatic agent. The powdered gelatine is provided in a full glass jar with a metal lid or in a sachet, each of which are to be opened and the contents of which, i.e. the gelatine, are to be poured into a sterile beaker or bowl.

US 5,645,849 claims a haemostatic patch comprising a biodegradable gelatine matrix, a haemostatic-promoting amount of thrombin and epsilon aminocaproic acid.

JP 62221357 discloses a skin ointment for promoting a haemostatic effect comprising thermoplastic resin or rubber dissolved in solvent and contains dispersed gelatine powder. The product is an ointment comprising thermoplastic resin or rubber and a fine powder of collagen, gelatine or chitosan.

FR 2679772 relates to particulate material to create an embolism comprising a polymer coated with a haemostatic or thrombonic agent. The haemostatic agent may be a finely divided gelatine powder.

US 6,096,309 relates to a haemostatic composition comprising thrombin and a mixture of non-microfibrillar collagen and microfibrillar collagen in an aqueous medium wherein the microfibrillar collagen has an average fibril diameter of about 3-30 nm.

US 4,515,637 relates to both a method of forming a collagen-thrombin haemostatic composition and to a lyophilised collagen product, comprising collagen and thrombin.

US 6,045,570 relates to a gelatine powder for use as a haemostatic agent and to a biological sealant comprising a gelatine slurry which includes milled gelatin powder. The slurry preferably comprises Gelfoam® powder mixed with a diluent selected from saline and water. The slurry demonstrates superior flow characteristics in that it exhibits minimal dilatency and can be easily injected or introduced through catheter lumens, especially small lumens. The product therefore has very fluid characteristics.

US 6,060,461 relates to particles, in particular dextran particles, having a particle size from 0.5-1000 μm and an average pore diameter from 0.5-1000 nm. It is disclosed that such particles may be used for enhancing clot formation on a wound by administering the particles in the form of a dry powder.

US 3,930,052 relates to cold-water-soluble gelatine compositions of different particle size.

US 5,225,536 is directed to particles of gelatine and amino acids. It is stated that such particles are suitable for being blended with various resins. The particle size distribution is so that most particles have a particle size of from 1.5 to 9.0 μm.

US 2003/0012741 relates to a process for preparing micronised collagen. It is stated that the particle size should not exceed 20 μm in order to optimise adhesion to the wound surface.

Various haemostatic sprays are commercially available:

Traumacel S® is a haemostatic dusting powder in a pressurised spray, the active component being a hydrogen calcium salt of oxidised cellulose.

Traumacel P® is a is a powdered haemostatic agent comprising a calcium salt of oxidised cellulose (carboxymethylcellulose calcium) which is applied as dry powder onto a bleeding area.

Avitene® is a microfibullar collagen haemostat "flour" typically applied dry.

Arista® is a haemostatic spray based on microporous polysaccharide hemospheres as described in US 6,060,461 (see above).

**SUMMARY OF THE INVENTION**

In a first aspect, the present invention relates to a powder delivery system containing a chamber storing a composition comprising gelatine or collagen powder having a mean particle size of at least 10 μm, said chamber having at least one discharge opening sized for distributing said composition.

In another aspect, the present invention relates to a powder delivery system containing a chamber storing a composition consisting of gelatine or collagen powder having a mean particle size of at least 10 μm, said chamber having at least one discharge opening sized for distributing said composition.

In a further aspect, the present invention relates to a composition as defined herein, as well as to a composition as defined herein for use as a medicament. In an interesting embodiment of the invention the composition is in the form of a gel.

In an even further aspect, the present invention relates to a method of promoting haemostasis in a patient in need thereof, said method comprising spraying a composition as defined herein onto at least a portion of the area where bleeding occurs.

In a still further aspect, the present invention relates to the use of gelatine or collagen powder having a mean particle size of at least 10 μm for the manufacture of a composition as defined herein for promoting haemostasis, wherein said composition is sprayed onto at least a portion of the area where bleeding occurs.

Moreover, the present invention also relates to gelatine or collagen powder compositions obtainable by or obtained by the method of the invention.

The present invention also relates to a powder delivery system containing a chamber for storing a powder composition, said chamber comprising at least one discharge opening

sized for distributing said composition and a protective structure arranged at the discharge opening.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention concerns a "ready-to-use" haemostatic spray which may be used acute as well as prophylactic. One advantage of using a haemostatic spray as compared to the more traditionally used sponges is that the haemostatic agent (in this case gelatine or collagen) can be applied in a thin layer over a relatively large area and that it may be applied to areas of the body that can be hard to reach with traditional sponges.

Although haemostatic sprays based on oxidised cellulose do exist there is a need for haemostatic sprays which contain a material suitable for effecting haemostasis and, at the same time, is more biocompatible than is oxidised cellulose. The present inventor provides a haemostatic spray based on micronised and/or finely pulverised particles of gelatine or collagen. Evidently, gelatine and collagen resembles the skin components to a much higher degree than do oxidised cellulose. Consequently, the haemostatic spray disclosed herein is considered safer and may provide fewer side effects, such as inflammation caused by a response from the immune system, than will haemostatic sprays based on oxidised cellulose.

In addition, the micronised and/or finely pulverised particles disclosed herein have a significantly higher wetability as compared to the conventionally used particles. As wetability is closely related to the capability of absorbing liquids, such as blood, the powder is providing for an improved haemostatic effect compared to conventionally used powder, such as gelatine powder.

In the present context, the term "micronised and/or finely pulverised " is intended to mean particles reduced in size to a mean particle size of less than about 250 μm.

As the price of gelatine is approximately one-third of the price of collagen, gelatine is preferred over collagen for economical reasons.

### Gelatine or Collagen Powder

The present inventor has found that the micronised and/or finely pulverised particles of gelatine or collagen powder produced by the method disclosed herein have a small mean particle size. Thus, compared to traditional sponges or powders, a lower amount of gelatine or collagen may be needed to obtain haemostasis when administered in the form of a spray, due to a faster and more efficient haemostasis. Surprisingly, a dramatic

improvement of the wetability of the powder was found when testing the powder by the *in vitro* wetability method described in the experimental section, i.e. the powder disclosed herein was found to absorb the applied liquid instantly. The improvement of wetability is likely to have a similar effect on the absorption capacity of the powder and consequently on the haemostatic effect. The mechanism of the improved effect is not fully understood, though the effect may result from the small particle size which facilitates the access of the blood to the particles. Furthermore, the improved effect might be caused by a high surface area.

From the results obtained by the wetability test as illustrated in Figs. 9 and 10, it is evident that the wetability is remarkably improved in the powder according to the invention. The skilled person will understand that the wetability of the powder relates to the absorption of a liquid, such as blood. Further it will be understood that a powder with an improved wetability provides for a more efficient haemostatic effect. As the improved powder has a higher wetability the amount of liquid, such as blood, absorbable will be higher providing for an efficient haemostatic effect. The skilled person will understand that there is a correlation between a powder capable of absorbing relative large amounts of liquids and a high wetability.

Fig. 9 illustrates a gelatine powder according to the present invention at time-points from 0 to 82 seconds after having a drop of saline applied on the surface. The illustrations are recorded according to the parameters described in Example 6.

Fig. 10 illustrates a conventional gelatine powder (Surgifoam® Powder) at time-points from 0 to 144 second after having a drop of saline applied on the surface. The illustrations are recorded according to the parameters described in Example 6.

Although gelatine or collagen are currently the preferred materials, it will be understood by the skilled person that in principle any biologically absorbable material may be used for the purposes described herein. Thus, materials other than gelatine or gelatine may be any material, which is known to be suitable for preparation of sponges and powder and, at the same time, being biologically absorbable. Examples of suitable biologically absorbable materials include (in addition to gelatine and collagen) chitin, chitosan, alginate, cellulose, polyglycolic acid, polyacetic acid and mixtures thereof. It will be understood that various forms thereof, such as linear or cross-linked forms, salts, esters and the like may also be used as the biologically absorbable material to be included in the haemostatic powder of the invention.

"Biologically absorbable" is a term which in the present context is used to describe that the materials of which the said powder are made can be degraded in the body to smaller molecules having a size which allows them to be transported into the blood stream. By said degradation and absorption the said powder materials will gradually be removed from the site of application. For example, denatured gelatine can be degraded by proteolytic tissue enzymes to absorbable smaller molecules, whereby the denatured gelatine powder when applied in tissues typically is absorbed within about 3-6 weeks and when applied on bleeding surfaces and mucous membranes typically within 3-5 days.

In a preferred embodiment of the invention, the biologically absorbable material is gelatine. Gelatine is preferred since gelatine is highly biologically absorbable. Furthermore, gelatine is highly biocompatible, meaning that it is non-toxic to an animal, such as a human being, when/if entering the blood stream or being in long-term contact with human tissues.

The gelatine typically originates from a porcine source, but may originate from other animal sources, such as from bovine or fish sources. The gelatine may also be synthetically made, i.e. made by recombinant means.

The collagen typically originates from a bovine source, but may originate from other animal sources. The collagen may also be synthetically made, i.e. made by recombinant means.

As mentioned above, the surface area is an important parameter of the gelatine or collagen powder/particles and, generally, the specific surface area is preferably at least 0.25 $m^2/g$ (e.g. 0.25-3.00 $m^2/g$ or 0.25-2.00 $m^2/g$) such as at least 0.50 $m^2/g$ (e.g. 0.50-3.00 $m^2/g$ or 0.50-2.00 $m^2/g$), more preferably at least 0.75 $m^2/g$ (e.g. 0.75-3.00 $m^2/g$ or 0.75-2.00 $m^2/g$), such as at least 0.80 $m^2/g$ (e.g. 0.80-3.00 $m^2/g$ or 0.80-2.00 $m^2/g$). In some particular interesting embodiments, the specific surface area is at least 0.90 $m^2/g$ (e.g. 0.90-3.00 $m^2/g$ or 0.90-2.00 $m^2/g$), such as at least 1.00 $m^2/g$ (e.g. 1.00-3.00 $m^2/g$ or 1.00 to 2.00 $m^2/g$). In even further embodiments of the invention, the specific surface area may be at least 1.25 $m^2/g$ (e.g. 1.25-3.00 $m^2/g$ or 1.25-2.00 $m^2/g$), such as at least 1.50 $m^2/g$ (e.g. 1.50-3 $m^2/g$ or 1.50-2.00 $m^2/g$). The specific surface is conveniently determined by gas adsorption (BET)

As will be acknowledged by the skilled person, a powder with a very small particle size, such as a mean particle size of less than about 10 $\mu$m, will give cause technical problems due to poor flowability. Further will a very small particle size give problems with dust while applying the powder. Therefore, the mean particle size of the powder must therefore be a

compromise between particles of a mean particle size of at least 10 μm. On the other hand, the particles should not be too large, i.e. the particles should have a mean particle size of less than 250 μm. Thus, in a preferred embodiment of the invention, the mean particle size of the powder is at least 20 μm, such as at least 30 μm, e.g. at least 40 μm, more preferably at least 50 μm, such as at least 60 μm, e.g. at least 70 μm. Analogously, the mean particle size of the powder is preferably less than 200 μm, such as less than 175 μm, e.g. less than 150 μm, more preferably less than 125 μm, such as less than 100 μm, e.g. less than 90 μm.

Stated differently, the mean particle size is in the range of 10-250 μm, such as in the range of 20-250 μm, e.g. in the range of 30-250 μm. In a preferred embodiment of the invention, the mean particles size is in the range of 20-200 μm, such as in the range of 30-175 μm, e.g. in the range of 40-175 μm, more preferably in the range of 50-150 μm, such as in the range of 55-125 μm, e.g. in the range of 60-100 μm. Most preferably, the mean particle size is in the range of 70-90 μm.

When used herein, the term "mean particle size" is defined with reference to the examples provided herein, i.e. the mean particle size is based on laser diffraction measurements.

Conventionally used gelatine powder, such as Surgifoam® Powder, has a particle size distribution where:
10% by volume is less than approximately 90 μm,
50% by volume is less than approximately 350 μm, and
90% by volume is less than approximately 700 μm.

The particles described herein preferably have a particle size distribution so that at least 90% by volume of the particles have a particle size below 250 μm, such as below 200 μm, e.g. below 190 μm, more preferably below 180 μm, such as below 170 μm. In addition, the particle size distribution is preferably so that at least 90% by volume of the particles have a particle size above 5 μm, such as above 10 μm, e.g. above 12 μm, in particular above 15 μm. In other words, the particle size distribution is preferably so that at least 80% by volume of the particles have a particle size of 5-250 μm, preferably of 5-200 μm, such as of 10-190 μm, e.g. of 12-180 μm, in particular of 15-170 μm.

The individual gelatine or collagen particles may be spherical or non-spherical, such as "rod-like" or "flake-like" and they may be "curved" as can be seen on Figs. 1A and 1B. However, independently of the actual physical form of the particles, a requirement of the particles is that they should exhibit excellent flowability properties or expressed differently, the particles should not be too cohesive. Flowability may, for example, be expressed in

terms of flow rate (g/sec) and may be measured in a standardised funnel as described Ph. Eur. using a specified aperture diameter. Alternatively, cohesion may be measured in a Powder Flow Analyser as described by Freeman in *Pharmaceutical Technology Europe*, January 2004, pp. 41-43. Preferably, the cohesion index, when measured by the above-mentioned Powder Flow Analyser method is at the most 150, such as at the most 140, e.g. at the most 130, more preferably at the most 120, such as at the most 110, in particular at the most 100, such as at the most 90, e.g. at the most 80, at the most 70, at the most 60 or at the most 50.

Furthermore, the gelatine or collagen particles described herein must have a suitable density. When used herein, the term "density" refers to either "poured density", "tapped density" or "particle density" as defined in Ph. Eur. On the one hand, the density of the particles should not be too low as the particles would then have a tendency to dust upon application to the wound area. On the other hand, the density should not be too high as the flowability properties would then not be satisfactory. Accordingly, the gelatine or collagen powder preferably has a poured density in the range of 0.05-0.3 g/ml, such as in the range of 0.06-0.25 g/ml, e.g. in the range of 0.07-0.20 g/ml, more preferably in the range of 0.075-0.15 g/ml. Similarly, the gelatine or collagen powder preferably has a tapped density in the range of 0.075-0.4 g/ml, such as in the range of 0.1-0.3 g/ml, e.g. in the range of 0.125-0.25 g/ml, more preferably in the range of 0.15-0.25 g/ml.

**Gelatine or Collagen Powder in Dry Form**

The composition described herein will normally be in dry form. Accordingly, in a preferred embodiment of the invention the delivery system contains a composition comprising dry gelatine or collagen powder.

In the present context the term "dry" when used in connection with the terms "powder" or "particle" means that no liquid substances, such as liquid water, organic solvents, etc., are present in the gelatine or collagen powder composition. Accordingly, compositions which are in the form of solutions, dispersions, suspensions, gels, pastes, and the like are not encompassed by the terms "dry powder" or "dry particle". The powder composition may, however, have a certain moisture content provided that the flowability properties of the powder is not adversely affected. Typically, the water (moisture) content of the powder is at the most 20% (w/w), such as at the most 18% (w/w), preferably at the most 16% (w/w), such as at the most 15% (w/w), more preferably at the most 14% (w/w), such as the most 13% (w/w), in particular at the most 12% (w/w), such as at the most 11% (w/w).

As will be understood, once the composition is sprayed onto the wound area it is critical that the powder adheres to the application site, i.e. the composition must be sufficiently tacky to adhere to the wound area. Accordingly, in an interesting embodiment of the invention the composition further comprises an agent, which improves the adhesive properties of the composition. As the composition is typically applied to the wound area and hence may enter the blood stream of the patient, it is of utmost importance that the above-mentioned agent is biocompatible, i.e. non-toxic to an animal, such as a human being, when/if entering the blood stream or being in long-term contact with human tissue. In other words, the term "biocompatible" means that the agent in question has the capability to coexist with living tissues or organisms without causing harm, i.e. without giving rise to adverse side-effects.

Suitable agents, which may improve the adhesive properties (or the tackiness) of the composition are well-known to the person skilled in the art. One class of suitable agents include saccharides, such as monosaccharides, disaccharides, oligosaccharides, polysaccharides, and combinations thereof.

When used herein the term "saccharide", as well as the terms "monosaccharide", "disaccharide", "oligosaccharide" and "polysaccharide", also encompasses derivatives thereof, such as saccharides comprising one or more aminosugar units. In the present context, an aminosugar unit is a sugar unit wherein at least one of the hydroxy groups available in the sugar unit has been substituted by an amino group or an alkanoylated amino group such as an acetylated amino group. Accordingly, it will be understood that saccharides containing one or more glucosamine and/or N-acetylglucosamine unit(s) are also encompassed by the above-mentioned terms. Apart from the aminosugar units, the saccharide may contain unsubstituted sugar units or sugar units substituted with e.g. alkoxy (such as 2,3-dimethylglucose) or acyloxy.

Specific examples of monosaccharides include glucose, mannose, fructose, threose, gulose, arabinose, ribose, erythrose, lyxose, galactose, sorbose, altrose, tallose, idose, rhamnose, allose, and derivatives thereof, e.g. pentosamines, hexosamines, such as glucosamine or N-acetylglucosamine, and glucoronic acid. In particular glucose is preferred.

Specific examples of disaccharides include sucrose, maltose, lactose, cellubiose as well as derivatives thererof. In particular sucrose is preferred.

Specific examples of polysaccharides include glycogen, chitin, chitosan, starch such as potato starch, as well as combinations thereof. Specific examples of polysaccharide

derivatives include glycosaminoglycans such as chondroitin, chondroitin sulfate, hyaluronic acid, dermatan sulfate and keratan sulfate; aminated dextrans including DEAE-dextran; aminated starch, aminated glycogen, aminated cellulose, aminated pectin, and salts, complexes, derivatives and mixtures thereof.

In an interesting embodiment of the invention, the composition further comprises an agent which improves the adhesive properties of said composition, where said agent is selected from the group consisting of glucose, sucrose, and a mixture thereof.

Other examples of agents which improve the adhesive properties of the composition include hydrocarbon resins, rosin resins and terpene resins. Hydrocarbon resins are commercially available under the tradenames Escorez® from ExxonMobil; Regalite®, Piccotac® and Picco® from Eastman; Indopol® from BP or Arkon®. Examples of rosin esters include esters of hydrogenated wood rosin e.g. pentaerythritol ester of hydrogenated wood rosin, esters of partially hydrogenated wood rosin e.g. pentaerythritol esters of partially hydrogenated wood rosin, esters of wood rosin, esters of modified wood rosin, esters of partially dimerized rosin, esters of tall oil rosin, esters of dimerized rosin, and similar rosins, and combinations and mixtures thereof. Such rosin esters are commercially available under the tradenames Foral®, Foralyn®, Pentalyn®, Permalyn® and Staybelite®.

Further examples of agents which improve the adhesive properties of the composition include Gum Karaya, sometimes known as Sterculia gum, Gum Arabicum, Gum Karrageenan, celluloseethers, such as sodium carboxymethylcellulose, Manuba Honey, casein, alginates or fatty acid esters, such as the fatty acid esters disclosed in WO 95/26715.

Thus, in an interesting embodiment of the invention, the composition comprises at least one agent which improves the adhesive properties of the composition. Evidently, the exact amount of agent may vary depending on what specific agent is being used, but the composition typically comprises 0.1-50% (w/w) of the agent, based on the total weight of the composition. Preferably, and in particular when the agent which improves the adhesive properties of the composition is a saccharide, the composition comprises 1-25% (w/w), such as 5-20% (w/w), e.g. 5-15% (w/w), 5-10% (w/w), or 10-15% (w/w), based on the total weight of the composition.

The agent may be applied to the composition by methods well-known to the person skilled in the art. For example, the agent may be in admixture with the gelatine or collagen powder and/or the agent may be coated on the surface of the gelatine or collagen powder.

The composition may contain additional substances, such as coagulation factors, antifibrinolytic agents, surfactants, growth factors to promote healing, antimicrobial agents, calcium ions to aid coagulation, adrenaline or other substances capable of constricting blood vessels.

Specific examples of coagulation factors include coagulation factors selected from the group consisting of thrombin, fibrinogen, aprotinin, fibronectin, factor XIII, factor VII, factor VIII, and combinations thereof. Such compounds may be of any mammalian origin, such as of porcine or human origin, or may be obtained by recombinant means by methods well-known to the skilled person. It will be understood that gelatine and collagen are not considered as being coagulation factors.

Antifibrinolytic agents may be selected from the group consisting of tranexamic acid, ε-aminocaproic acid, aprotinin, pepstatin, leupeptin, antipain, chymostatin, gabexate, and mixtures thereof. If present, the antifibrinolytic agent is preferably tranexamic acid.

Antimicrobial agents may be selected from bactericidal or bacteriostatic agents, such as antibiotics and sulphonamides, antiviral compounds, antimycotic agents and anti-infectives. Antibiotics may be selected from e.g. β-lactams, penicillins, cephalosporins, monobactams, macrolides, polymyxins, tetracyclines, chloramphenicol, thrimethoprim, aminoglycosides, clindamycin, and metronidazole; sulphonamides may as an example be selected from sulphadimidine or sulphadimethoxin; antimycotic agents may be selected from amphotericin B, ketoconazol and miconazol; and antiviral agent from idoxuridine andazidothymidin. Suitable antiinfectives may as an example be selected from halogens, chlorohexidine and quarternary ammonium compounds. Other examples of bactericidal or bacteriostatic compounds include silver ions, in particular in the form of silver ion complexes.

Surfactants may be selected from the group consisting of anionic surfactants, cationic surfactants, non-ionic surfactants and surface active biological modifiers.

Examples of anionic surfactants include surfactants selected from the group consisting of potassium laurate, triethanolamine stearate, sodium lauryl sulfate, sodium dodecylsulfate, alkyl polyoxyethylene sulfates, sodium alginate, dioctyl sodium sulfosuccinate, phosphatidyl glycerol, phosphatidyl inositol, phosphatidylserine, phosphatidic acid and their salts, glyceryl esters, sodium carboxymethylcellulose, bile acids and their salts, cholic acid, deoxycholic acid, glycocholic acid, taurocholic acid, glycodeoxycholic acid, and calcium carboxymethylcellulose. In particular sodium lauryl sulfate is preferred.

Examples of cationic surfactants include surfactants selected from the group consisting of quaternary ammonium compounds, benzalkonium chloride, cetyltrimethylammonium bromide, chitosans and lauryldimethylbenzylammonium chloride.

Examples of non-ionic surfactants include surfactants selected from the group consisting of polyoxyethylene fatty alcohol ethers, polyoxyethylene sorbitan fatty acid esters, polyoxyethylene fatty acid esters, sorbitan esters, polyoxyethylene sorbitan esters (such as Tween 80), glycerol monostearate, polyethylene glycols, polypropylene glycols, cetyl alcohol, cetostearyl alcohol, stearyl alcohol, aryl alkyl polyether alcohols, polyoxyethylene-polyoxypropylene copolymers, polaxamines, methylcellulose, hydroxycellulose, hydroxy propylcellulose, hydroxy propylmethylcellulose, noncrystalline cellulose, polysaccharides, starch, starch derivatives, hydroxyethylstarch, polyvinyl alcohol, and polyvinylpyrrolidone.

Examples of surface active biological modifiers include, e.g., albumin and casein.

However, in a preferred embodiment of the invention, the composition does not contain such additional substances, i.e. said composition does not contain coagulation factors, anti-fibrinolytic agents, surfactants and/or antimicrobial agents.

In one interesting embodiment of the invention the preparation comprises an agent that is incompatible with moisture and/or water. The embodiment might comprise both a dry powder and a liquid to be combined with the powder to form a paste immediately before use. In such an embodiment the dry powder and the liquid is kept separate under storage. The dry component and the liquid component might be contained in the same packaging while still kept without contact under storage. The agent incompatible with moisture and/or water can be an antimicrobial agents, a polysaccharide or a protein. The composition is in dry form under storage to improve stability. The composition can be contacted with water immediately before use.

Sponges of gelatine or collagen, in particular hardened sponges of gelatine (such as the commercially available Spongostan® sponges and Surgifoam® sponges) or collagen may be micronised by methods well known in the art. Thus, the compositions described herein may, e.g., be prepared by any suitable micronisation technique known to the skilled person, such as rotary bed, extrusion, granulation and treatment in an intensive mixer, milling (e.g. by using a hammer mill or a centrifugal mill), or spray drying.

The gelatine or collagen powder composition is preferably subjected to a sterilisation treatment by application of radiation, such as β-radiation. The dose typically lies in the range of 20-60 kGy, e.g. 25 kGy.

As indicated above, the gelatine and/or collagen powder compositions described herein may be used as a medicament. Accordingly, in a further aspect the present invention relates to a method of promoting haemostasis in a patient in need thereof, said method comprising spraying a composition as defined herein onto at least a portion of the area where bleeding occurs. In a still further aspect the present invention relates to the use of gelatine or collagen powder having a mean particle size of at least 10 μm for the manufacture of a composition as defined herein for promoting haemostasis, wherein said composition is sprayed onto at least a portion of the area where bleeding occurs.

The powder composition may be applied directly to surfaces and optionally, after being applied to the surface, held in place by pressure, e.g. by means of sponges, pads, dressings, webs, films, etc. or by other materials normally used in the medical practice. A preferred material for holding the composition in place after being applied to the wound area is surgical gauze or cotton gauze, optionally wetted in saline.

The powder delivery system of the invention may be used in an array of surgical procedures wherein bleeding control is desired, such as in orthopedic precedures, e.g. in connection with laminectomy, total hip replacement and hip revisions, knee surgery, spinal fusion, etc.; in cardiothoracic/cardiovascular procedures, such as in connection with CABGs, valve replacements, aotic surgery, abdominal aortic aneurisms, carotid endarterectomy and femoral-popliteal bypass, amongst others.

**Gelatine or Collagen in the Form of a Gel**

In another interesting embodiment of the invention the composition is in the form of a gel.

The term "gel" may be used interchangeable with words like "paste", "suspension" and the like. In the present context, the term "gel" refers to a solid or semi-solid disperse system wherein a solid material is dispersed in a liquid medium. The solid material may also be referred to as a gel-forming agent. Furthermore, a gel is characterised by having a dynamic viscosity above that of water.

As will be understood the solid material (or the gel-forming agent) of the gel is the gelatine particles or the collagen particles disclosed herein. Alternatively, the solid material may be a mixture of the gelatine and collagen particles disclosed herein.

The gel may be obtained by suspending the gelatine or collagen particles described herein in a liquid medium, in particular in an aqueous medium. Typically, about 1-20 ml liquid medium is employed per gram gelatine or collagen, preferably 2-18 ml/g, such as 3-16 ml/g, e.g. 4-14 ml/g, more preferably 6-14 ml/g, in particular 8-12 ml/g.

As mentioned above, the liquid medium is preferably an aqueous medium. More preferably the aqueous medium contains salts, such as sodium chloride, dissolved therein. Most preferably, the aqueous medium is saline.

As will be understood, once the composition is applied onto the wound area it is critical that the composition adheres to the application site, i.e. the composition must be sufficiently tacky to adhere to the wound area. Accordingly, in an interesting embodiment of the invention the composition further comprises an agent, which improves the adhesive properties of the composition. As the composition is typically applied to the wound area and hence may enter the blood stream of the patient, it is of utmost importance that the above-mentioned agent is biocompatible, i.e. non-toxic to an animal, such as a human being, when/if entering the blood stream or being in long-term contact with human tissue. In other words, the term "biocompatible" means that the agent in question has the capability to coexist with living tissues or organisms without causing harm, i.e. without giving rise to adverse side-effects.

Suitable agents, which may improve the adhesive properties (or the tackiness) of the composition are well-known to the person skilled in the art. One class of suitable agents include saccharides, such as monosaccharides, disaccharides, oligosaccharides, polysaccharides, and combinations thereof.

When used herein the term "saccharide", as well as the terms "monosaccharide", "disaccharide", "oligosaccharide" and "polysaccharide", also encompasses derivatives thereof, such as saccharides comprising one or more aminosugar units. In the present context, an aminosugar unit is a sugar unit wherein at least one of the hydroxy groups available in the sugar unit has been substituted by an amino group or an alkanoylated amino group such as an acetylated amino group. Accordingly, it will be understood that saccharides containing one or more glucosamine and/or N-acetylglucosamine unit(s) are also encompassed by the above-mentioned terms. Apart from the aminosugar units, the saccharide may contain unsubstituted sugar units or sugar units substituted with e.g. alkoxy (such as 2,3-dimethylglucose) or acyloxy.

Specific examples of monosaccharides include glucose, mannose, fructose, threose, gulose, arabinose, ribose, erythrose, lyxose, galactose, sorbose, altrose, tallose, idose,

rhamnose, allose, and derivatives thereof, e.g. pentosamines, hexosamines, such as glucosamine or N-acetylglucosamine, and glucoronic acid. In particular glucose is preferred.

Specific examples of disaccharides include sucrose, maltose, lactose, cellubiose as well as derivatives thererof. In particular sucrose is preferred.

Specific examples of polysaccharides include glycogen, chitin, chitosan, starch such as potato starch, as well as combinations thereof. Specific examples of polysaccharide derivatives include glycosaminoglycans such as chondroitin, chondroitin sulfate, hyaluronic acid, dermatan sulfate and keratan sulfate; aminated dextrans including DEAE-dextran; aminated starch, aminated glycogen, aminated cellulose, aminated pectin, and salts, complexes, derivatives and mixtures thereof.

In an interesting embodiment of the invention, the composition further comprises an agent which improves the adhesive properties of said composition, where said agent is selected from the group consisting of glucose, sucrose, hyaluronic acid, sodium hyaluronate and a mixture thereof.

Other examples of agents which improve the adhesive properties of the composition include hydrocarbon resins, rosin resins and terpene resins. Hydrocarbon resins are commercially available under the tradenames Escorez® from ExxonMobil; Regalite®, Piccotac® and Picco® from Eastman; Indopol® from BP or Arkon®. Examples of rosin esters include esters of hydrogenated wood rosin e.g. pentaerythritol ester of hydrogenated wood rosin, esters of partially hydrogenated wood rosin e.g. pentaerythritol esters of partially hydrogenated wood rosin, esters of wood rosin, esters of modified wood rosin, esters of partially dimerized rosin, esters of tall oil rosin, esters of dimerized rosin, and similar rosins, and combinations and mixtures thereof. Such rosin esters are commercially available under the tradenames Foral®, Foralyn®, Pentalyn®, Permalyn® and Staybelite®.

Further examples of agents which improve the adhesive properties of the composition include Gum Karaya, sometimes known as Sterculia gum, Gum Arabicum, Gum Karrageenan, celluloseethers, such as sodium carboxymethylcellulose, Manuba Honey, casein, alginates or fatty acid esters, such as the fatty acid esters disclosed in WO 95/26715.

The composition may contain additional substances, such as coagulation factors, antifibrinolytic agents, surfactants, preservatives, solubilising agents, growth factors to

promote healing, antimicrobial agents, calcium ions to aid coagulation, adrenaline or other substances capable of constricting blood vessels.

Specific examples of coagulation factors include coagulation factors selected from the group consisting of thrombin, fibrinogen, aprotinin, fibronectin, factor XIII, factor VII, factor VIII, and combinations thereof. Such compounds may be of any mammalian origin, such as of porcine or human origin, or may be obtained by recombinant means by methods well-known to the skilled person. It will be understood that gelatine and collagen are not considered as being coagulation factors.

Antifibrinolytic agents may be selected from the group consisting of tranexamic acid, ε-aminocaproic acid, aprotinin, pepstatin, leupeptin, antipain, chymostatin, gabexate, and mixtures thereof. If present, the antifibrinolytic agent is preferably tranexamic acid.

Antimicrobial agents may be selected from bactericidal or bacteriostatic agents, such as antibiotics and sulphonamides, antiviral compounds, antimycotic agents and anti-infectives. Antibiotics may be selected from e.g. β-lactams, penicillins, cephalosporins, monobactams, macrolides, polymyxins, tetracyclines, chloramphenicol, thrimethoprim, aminoglycosides, clindamycin, and metronidazole; sulphonamides may as an example be selected from sulphadimidine or sulphadimethoxin; antimycotic agents may be selected from amphotericin B, ketoconazol and miconazol; and antiviral agent from idoxuridine andazidothymidin. Suitable antiinfectives may as an example be selected from halogens, chlorohexidine and quarternary ammonium compounds. Other examples of bactericidal or bacteriostatic compounds include silver ions, in particular in the form of silver ion complexes.

Surfactants may be selected from the group consisting of anionic surfactants, cationic surfactants, non-ionic surfactants and surface active biological modifiers.

Examples of anionic surfactants include surfactants selected from the group consisting of potassium laurate, triethanolamine stearate, sodium lauryl sulfate, sodium dodecylsulfate, alkyl polyoxyethylene sulfates, sodium alginate, dioctyl sodium sulfosuccinate, phosphatidyl glycerol, phosphatidyl inositol, phosphatidylserine, phosphatidic acid and their salts, glyceryl esters, sodium carboxymethylcellulose, bile acids and their salts, cholic acid, deoxycholic acid, glycocholic acid, taurocholic acid, glycodeoxycholic acid, and calcium carboxymethylcellulose. In particular sodium lauryl sulfate is preferred.

Examples of cationic surfactants include surfactants selected from the group consisting of quaternary ammonium compounds, benzalkonium chloride, cetyltrimethylammonium

bromide, chitosans and lauryldimethylbenzylammonium chloride.

Examples of non-ionic surfactants include surfactants selected from the group consisting of polyoxyethylene fatty alcohol ethers, polyoxyethylene sorbitan fatty acid esters, polyoxyethylene fatty acid esters, sorbitan esters, polyoxyethylene sorbitan esters (such as Tween 80), glycerol monostearate, polyethylene glycols, polypropylene glycols, cetyl alcohol, cetostearyl alcohol, stearyl alcohol, aryl alkyl polyether alcohols, polyoxyethylene-polyoxypropylene copolymers, polaxamines, methylcellulose, hydroxycellulose, hydroxy propylcellulose, hydroxy propylmethylcellulose, noncrystalline cellulose, polysaccharides, starch, starch derivatives, hydroxyethylstarch, polyvinyl alcohol, and polyvinylpyrrolidone.

Examples of surface active biological modifiers include, e.g., albumin and casein.

Examples of preservatives include benzoic acid, sorbic acid, parabens (e.g. methyl-p-hydroxy benzoic acid, ethyl-p-hydroxy benzoic acid, propyl-p-hydroxy benzoic acid, butyl-p-hydroxy benzoic acid and mixtures thereof), benzyl alcohol, chlorhexidine or benzalkonium chloride.

Specific examples of solubilising agents include water-miscible organic compounds such as glycerol or propylene glycol.

Such gel or gel-like compositions may be applied to the wound area in a manner well-known to the person skilled in the art.

**Delivery System for Powder compositions**

The powder delivery system is preferably a hand-held delivery system, which may be used, for example, by surgeons during operations to arrest bleedings.

A suitable powder delivery system comprises a chamber storing a powdered composition, such as a composition comprising gelatine or collagen powder having a mean particle size of at least 10 μm. The delivery system further contains at least one discharge opening sized for distributing the composition. The discharge opening should preferably be sized for distributing the composition to a surface, such as a wound, skin, an organ, etc., in controlled amounts, in particular so that the risk of overdosing is avoided.

The delivery system may be a simple salt shaker-like device. However, in a preferred embodiment the device comprises an elongate tip for distribution of the composition, whereby it is possible more accurately and faster to apply the composition at the right place on a bleeding area and further in confined space regions. The tip can be

interchangeable so that the most suitable tip can be selected for the specific application of the composition. The tip opening typically has a diameter of from 0.05-5 mm, preferably of from 0.05-4 mm, such as of from 0.05-3 mm, e.g. of from 0.075-2.5 mm, such as about 1 mm, about 1.5 mm or about 2.0 mm.

The delivery system may be powered and e.g. comprise an electric motor rotating a plate with holes to register with corresponding holes at the discharge opening. However, in a preferred embodiment the delivery system is manually operable, such as by shaking or squeezing the system, thereby keeping the cost and complexity of the system at a minimum.

Alternatively or additionally the delivery system may comprise a resilient wall portion or bellows, such that the resilient wall portion or bellows may be compressed to expel the composition from the chamber through the discharge opening. This is a cost effective and simple embodiment, which further is intuitive and easy to use. Additionally, the composition may be discharged to the surface very precisely, as the discharge opening is kept steady.

As will be evident to the skilled person, the delivery system may comprise some kind of powered mechanism to compress the resilient wall portion or bellows. In a preferred embodiment, however, the resilient wall portion or bellows is adapted to be manually activated, such as by finger pressure, to discharge at least part of the composition.

The delivery system can be manufactured in a conventional way, which will be known to the person skilled in the art. The system is preferably made of one or more suitable plastic materials, such as polypropylene and/or polyethylene. The dimensions of the system may vary depending on the actual design. It is important, however, that the system should still be manually operable by one hand. Typically, a total amount of 0.5-5 g, such as 1-3 g of the powder composition is loaded into the delivery system.

In a particular preferred embodiment of the invention, the delivery system may further comprise a protective structure arranged at the discharge opening. What is achieved is that the discharge opening is, at least to some extent, isolated from the surroundings. This, in turn, is advantageous when the delivery system is used in connection with surgery where contamination and, in particular, clogging of the discharge opening due to blood coagulation, may then be minimised or completely avoided.

The protective structure may be constructed in various ways. The protective structure may surround the discharge opening but have a relative open structure as show in Fig. 4.

Alternatively, the protective structure may surround the discharge opening and be in the form of a grid. In a preferred embodiment the protective structure is a skirt portion arranged to extend from the discharge opening.

The protective structure may be made from the same material as the delivery system, and the protective structure may form an integral part of the delivery system or it may be a non-integral part, such as a removable part, of the delivery system.

Since a delivery system comprising a protective structure as described above is believed to be novel and inventive *per se*, the present invention also relates to a powder delivery system containing a chamber for storing a powder composition, said chamber comprising at least one discharge opening sized for distributing said composition and a protective structure arranged at the discharge opening.

It will be understood that said delivery system preferably contains a gelatine or collagen powder composition as described hereinbefore. However, the delivery system may contain any powder composition suitable for haemostatic purposes.

Examples of specific materials useful in the practice of the present invention comprise materials from within the classes of polysaccharides, cellulosics, polymers (natural and synthetic), inorganic oxides, ceramics, zeolites, glasses, metals, and composites. Preferred materials are of course non-toxic and are provided as a sterile supply. The particulate polysaccharides may be provided as starch, cellulose and/or pectins, and even chitin may be used (animal sourced from shrimp, crab and lobster, for example). Glycosaccharides or glycoconjugates which are described as associations of the saccharides with either proteins (forming glycoproteins, especially glycolectins) or with a lipid (glycolipid) are also useful. These glycoconjugates appear as oligomeric glycoproteins in cellular membranes.

Ceramic materials may be provided from the sintering, or sol-gel condensation or dehydration of colloidal dispersions of inorganic oxides such as silica, titanium dioxide, zirconium oxide, zinc oxide, tin oxide, iron oxide, cesium oxide, aluminum oxide and oxides of other metal, alkaline earth, transition, or semimetallic chemical elements, and mixtures thereof. By selection of the initial dispersion size or sol size of the inorganic oxide particles, the rate of dehydration, the temperature at which the dehydration occurs, the shear rate within the composition, and the duration of the dehydration, the porosity of the particles and their size can be readily controlled according the skill of the ordinary artisan.

With regard to cellulosic particles, natural celluloses or synthetic celluloses (including cellulose acetate, cellulose butyrate, cellulose propionate, oxidised cellulase and salts

thereof, in particular calcium salts thereof) as well as fibers and microfibers of cellulose-based materials may be used in accordance with the invention.

It will be understood that where the materials, whether of cellulose or other compositions, have a size which may be too large for a particular application, the particles may be ground or milled to an appropriate size. This can be done by direct mortar and pestle milling, ball milling, crushing (as long as the forces do not compress out all of the porosity), fluidised bed deaggregation and size reduction, and any other available physical process.

A particularly interesting and commercially available material comprises polysaccharide beads, such as dextran beads which are available as Sephadex®. beads from Pharmacia Labs. These are normally used in surgery as an aid to debridement of surfaces to help in the removal of damaged tissue and scar tissue from closed wounds. In the following the device will be more thoroughly explained with reference to the drawings in which:

Fig. 2 is a sketch of a powder delivery system according to the invention.

Fig. 3 is an alternative embodiment of the delivery system.

Fig. 4 is a sketch of a protective structure for the delivery system.

Fig. 2 schematically illustrates a simple embodiment of the delivery system according to the invention. The delivery system (1) comprises a chamber (2) storing a composition (3) comprising gelatine or collagen powder, and the chamber (2) has at least one discharge opening (4). The shown delivery system (1) further comprises a plug with sift (5). As will be appreciated by the skilled person the composition (3) in the chamber (2) may be distributed by turning the delivery system up-side-down and if necessary or convenient shaking the system. The composition (3) will then leave the chamber (2) through the discharge opening (4) and the sift (5) by influence of gravity. As shown, the delivery system may further be equipped with an extended nozzle or elongate tip (6) which may further be provided with a reclosure cap (7). The chamber (2) may have walls (8) of a resilient or flexible material, such as plastic, so it is possible to squeeze the walls (8) inwardly forcing the composition (3) out of the chamber (2), e.g. with the fingers of one hand only.

An alternative embodiment of the delivery system 1 is shown in Fig. 3. The delivery system (1) comprises a chamber (2) comprising a composition (3), and a bellows (9) which when squeezed generates air pressure forcing air through the chamber (2) and

driving composition (3) into the extended nozzle and out through the discharge opening (4). The delivery system (1) may be provided with a one-way inlet valve (10) as shown to let air enter the bellows (9) from the outside. The delivery system (1) may further be provided with a one-way outlet valve (11) to ensure that powder is not sucked into the bellows (9).

A special distance protective structure is illustrated in Fig. 4. The embodiment shown comprises a ring (12) supported by legs (13), so the discharge opening (4) of the extended nozzle cannot abut a surface. Alternatively, the protective structure may be a skirt (not shown) attached to the discharge opening (4), said skirt extending in front of the discharge opening (4) of the extended nozzle.

A further aspect of the delivery system is in the form of a pen-like device. This pen-like device is a device suitable for pressurised delivery of an agent wherein the delivery is through an outlet of a hollowed member upon compression of a bow engaged with a serrated edge portion of a serrated piston located within the hollowed membrane, so as to propel the piston in the direction of the outlet, said engagement being through an aperture in said hollowed tubular membrane. Compression of the engaged bow propels the piston in the direction of the outlet by a distance defined by the radius of the bow so as to deliver the agent. Release of the compression allows for the bow to return to its curved position of higher potential energy and to re-engage with a second serrated edge portion of the piston, said second serrated edge portion being distally positioned on the piston from the outlet.

As stated, the delivery is made in finite volumes defined by the radius of the bow in concert with the spacing of the serrated edges. The degree of compression can be so as to project the serrated piston by a distance of 1-4 serrations, such as 1, 2, 3, or 4 preferably 1, 2 and 3 serrations, more preferably 1 and 2 serrations. For instance, full compression propels the piston a distance of 2 serrations and slight compression propels the piston by a distance of 1 serration. In order for the bow to return to its position of maximal potential energy, it's resting position, it must re-engaged with a serration distally located on the piston from the outlet.

The hollowed member may be a hollowed tubular member with an inner diameter appropriate and suitable for the agent to be delivered. The agent may be in an array of forms such as in the form of a liquid, solid granules, powder, paste, suspension or emulsion.

In a typical embodiment, the radius of the bow is such that compression of its arch results in the projection of the serrated piston so as to deliver a volume of 0.05 to 2 ml per full compression, typically 0.075 to 1 ml, more typically 0.1 to 0.5 ml, such as 0.1, 0.2, 0.3, 0.4 and 0.5 ml.

The present inventors have found that the delivery is of a high pressure compared to conventional devices, and suitable for delivery of a powdered agent at a pressure of 50-200 N, such as 75-200 N, typically 100-180 N.

The bow of the pen-like device is typically located along the longitudinal axis of the hollow member so as to render the device easy to hold and use at the same time, such as by compression by the thumb. Figure 8 depicts an illustrative example of the pen-like device.

The invention is further illustrated by the following non-limiting examples.

## EXAMPLES

### Example 1A - Preparation of micronised gelatine powder

The gelatine powder was produced on a Retsch Centrifugal Mill with a screen size of 80 μm using a speed of 10,000 rpm. Hardened and sterilised gelatine sponges (Spongostan®) were cut into pieces of 0.5 $cm^2$ and about 750 mg material was milled at a time (until the screen was full). After each milling round the screen was cooled and cleaned by means of a vacuum cleaner. The gelatine powder was subsequently sterilised by β-radiation (approximately 25 kGy).

A SEM picture of the obtained powder is shown in Fig. 1A (at 500 magnification).

### Example 1B - Preparation of micronised gelatine powder

The gelatine powder was produced on a Fitzpatrick Hammer Mill RP-M5A with a screen size of 74 μm using a speed of 4,500 rpm. Hardened and sterilised gelatine sponges (Spongostan®) were cut into pieces of 3x7 cm. After milling the gelatine powder was sterilised by β-radiation (approximately 25 kGy).

A SEM picture of the obtained powder is shown in Fig. 1B (at 500 magnification).

### Example 2 - Determination of particle size

Determination of the particle size distribution on the gelatine powder samples prepared in Examples 1A and 1B was performed by laser diffraction using the following equipment and settings:

| | |
|---|---|
| Laser diffraction | Malvern Mastersizer 2000 |
| Dispersion unit | Scirocco 2000 |
| Software version | Mastersizer 2000, version 4 |
| Sample amount | ~0.25 g |
| No. of measurements* | 3 |
| Disperser pressure | 1.0 bar |
| Feed opening | 10 mm |
| Feed rate | 80-95% |
| Obscuration | 2-6% |
| Obscuration filtering | Enabled |
| Measurements integrations | Minimum 4000 (4 seconds) |
| Calculation model | Fraunhofer |
| Sensitivity | Enhanced |
| Evaluation model | General purpose |

*The result is calculated as an average result based on the light scattering patterns from each measurement. The average result is calculated using Malvern software.*

Figs. 5 and 6 give a graphical representation of the particle size distribution. As can be seen, the mean particle size for both samples was about 80 μm.

The following percentiles of the volume size distribution of the two samples were found:

| | |
|---|---|
| *Example 1A* | |
| $D_{10\%}$ | 27.3 μm |
| $D_{50\%}$ | 74.5 μm |
| $D_{90\%}$ | 159.9 μm |
| *Example 1B* | |
| $D_{10\%}$ | 16.7 μm |
| $D_{50\%}$ | 68.6 μm |
| $D_{90\%}$ | 152.4 μm |

*$D_{10\%}$, $D_{50\%}$, $D_{90\%}$ are the respective percentiles of the volume size distribution*

**Example 3 - Determination of water content**

Determination of the water content in the gelatine powder samples prepared in Examples 1A and 1B was performed by the "Loss On Drying" method described in Ph. Eur. Samples were analysed for 30 min. at 100°C using a Mettler Infrarottrockner LP16. Data were collected every second minute.

The following water content in the two samples were found:

| | |
|---|---|
| Example 1A | 10.0% (w/w) |
| Example 1B | 8.0 % (w/w) |

**Example 4 - Determination of apparent and particle density**

Determination of the apparent density (tapped density and poured density) of the gelatine powder samples prepared in Examples 1A and 1B was performed according to the methods described in Ph. Eur.

The following densities were found:

| | |
|---|---|
| *Example 1A* | |
| Tapped density | 0.23 g/ml |
| Poured density | 0.13 g/ml |
| *Example 1B* | |
| Tapped density | 0.17 g/ml |
| Poured density | 0.10 g/ml |

Determination of the particle density of the gelatine powder sample prepared in Example 1B was performed according to the pycnometric density method described in Ph. Eur.

| | |
|---|---|
| Particle density | 1.396 g/cm$^3$ |

**Example 5 - Determination of specific surface area**

Determination of specific surface area of the gelatine powder samples prepared in Examples 1A and 1B was performed by nitrogen adsorption using the following conditions:

| | |
|---|---|
| Analytical equipment | Micromeritics Gemini 2375 BET (SN: 683) |
| Gas | Nitrogen (quality 5.0) |
| Relative pressure | 0.050-0.300 |
| Evacuation rate | 300.0 mm Hg/min |
| Evacuation time | 5 minutes |
| Sample preparation | Dried for at least 24 h under vacuum at r.t. |

The following surface areas were found:

| | |
|---|---|
| *Example 1A* | |
| Specific surface area | 1.05 $m^2/g$ (1st measurement) |
| | 1.07 $m^2/g$ (2nd measurement) |
| | 1.06 $m^2/g$ (average) |
| *Example 1B* | |
| Specific surface area | 1.62 $m^2/g$ (1st measurement) |
| | 1.60 $m^2/g$ (2nd measurement) |
| | 1.61 $m^2/g$ (average) |

**Example 6 - Wetability and saline absorption**

<u>Wetability</u>

Wetability was assessed under a macroscope while the wetting process took place. The conventionally used Surgifoam® Powder was compared with the powder according to the invention. Each of the powders was applied onto separate microscopic glass slides by means of a Vacuum Dispensing Unit to achieve a homogeneous layer of powder.

Parameters:

Macroscope: Meiji UniMac Zoom Macroscope

Light source: Schot KL1500 Electronic (level 3)
Two-armed light wire: Fibre Optic Eluminator (light from two sides)
Camera: Sony XC-75CE series no. 94154 (black/white)
Software: Piccolo Capture Driver version 1.6, MCM design

The microscopic glass slide was placed under a macroscope and a picture was taken at the time-point of 0 seconds. After addition of a drop (35 μl) of saline, pictures were taken every 2 seconds. The zoom factor was 0.7 times enlargement and the objective was 2.5 times enlargement, resulting in a total of 1.75 times enlargement.

Fig. 9 at the time-point of 0 seconds depicts the dry powder according to the invention before adding saline. At the time-point of 2 seconds a drop of saline is added to the powder. The saline droplet can be recognised as a dark zone to the time-point of 2 seconds. From the zone, where the droplet landed, it starts spreading out in a ring at 4 seconds. The ring continues to spread out, as is recognised at the following time-points. As the ring is spreading, the zone encircled by the spreading saline-droplet continuously becomes darker due to wetting of the powder.

Fig. 10 at the time-point of 0 seconds depicts Surgifoam® Powder before adding saline. At the time-point of 2 seconds a drop of saline is likewise added to the powder. The droplet can be recognised as a partly dark zone where the droplet has landed. There is a remarkable difference when comparing with the powder according to the invention, as there still remain unwetted powder within the zone encircled by the droplet. In the Surgifoam® Powder no spreading of the saline-droplet is seen even after 144 seconds, i.e. the diameter of the droplet zone does not increase. Further, it should be noted that the powder at the position of the landing droplet is only partly wetted.

The obtained results from the wetability studies are compiled in the below Table.

| Distance from the centre of the droplet to the edge of the wetted area | | |
|---|---|---|
| Time (seconds) | Powder according to the invention (cm) | Surgifoam® Powder (cm) |
| 0 | 0 | 0 |
| 2 | 4 | 5.5 |
| 6 | 5 | 5.5 |
| 8 | 7 | 5.5 |
| 10 | 8.75 | 5.5 |
| 20 | 9.5 | 5.5 |
| 30 | 11 | 5.5 |
| 40 | 13 | 5.5 |
| 50 | 13.5 | 5.5 |
| 60 | 14 | 5.5 |

From the above results, as well as from Figs. 9 and 10, it is evident that the wetability of the powder according to the invention is significantly improved.

Saline absorption

The amount of absorbed saline was determined by weighing after exposure of the powder to saline for 0.5 minutes, 2 minutes and 5 minutes. The amount of saline absorbed by the powder according to the invention was compared to the amount absorbed by Surgifoam® Powder. The obtained results are compiled in the below Tables.

| Powder according to the invention | | | | |
|---|---|---|---|---|
| | Saline absorbed in gram | | | |
| Powder | 0.5 min | 2 min | 5 min | n= |
| 2 (g) | **3.7** | **7.3** | **9.5** | 5 |
| std. | 0.3 | 0.7 | 0.2 | |

| Surgifoam® Powder | | | | |
|---|---|---|---|---|
| | Saline absorbed in gram | | | |
| Powder | 0.5 min | 2 min | 5 min | n= |
| 2 (g) | **2.9** | **5.2** | **6.9** | 5 |
| std. | 0.4 | 1.0 | 1.8 | |

The above results show that the powder according to the invention is absorbing saline faster than Surgifoam® Powder and that the absorption capacity is higher. Thus, the absorption properties of the powder according to the invention is significantly improved.

**Example 7 - *In vitro* coagulation test in blood from humans**

The *in vitro* coagulation properties of the gelatine powder prepared as described in Example 1A above was investigated. The test powder denoted "Test powder I" was sterilised by 25 kGy β-radiation, whereas the test powder denoted " Test powder II" was sterilised by 55 kGy β-radiation

Samples of each test powder (30 mg) were placed in tubes and covered with fresh human blood (1 ml) using a ratio of 30 mg test powder/ml blood. The tubes were placed in a water bath at 37°C and were shaken regularly.

The time needed for total coagulation to occur was recorded for each sample.

Untreated controls, negative controls (treated with pieces of negative control plastic) and positive controls (treated with Fuller's Earth) were also tested.

Each test powder and control was assayed once with blood from four different human beings.

Results

| Treatment | Coagulation time (seconds) | | | | | |
|---|---|---|---|---|---|---|
| | Donor 1 | Donor 2 | Donor 3 | Donor 4 | Mean ± SD | % |
| Untreated control | 355 | 383 | 339 | 374 | 363 ± 20 | 100 |
| Negative control | 366 | 331 | 344 | 220 | 315 ± 65 | 87 |
| Positive control | 101 | 97 | 64 | 74 | 84 ± 18 | 23 |
| Test powder I | 109 | 139 | 99 | 146 | 123 ± 23 | 34 |
| Test powder II | 140 | 202 | 200 | 118 | 165 ± 43 | 45 |

As can be seen from the above coagulation data, the gelatine powder composition exhibits excellent coagulation properties with a coagulation time being in the range of 30-50% of the coagulation time of untreated controls.

**Example 8 - Evaluation on haemostatic efficacy in a porcine spleen model**

The objective of this study was to compare the *in vivo* efficacy of the gelatine powder prepared in Examples 1A and 1B with and without two different adhesive agents (glucose monohydrate and sucrose) when applied to small, freely bleeding incisions made in the spleen of a pig (female pig, 35 kg). The objective was furthermore to obtain knowledge concerning the amount of powder needed per bleeding.

The aim of this animal trial wa to compare the efficacy of dry absorbable gelatine powders added no or one of the two different adhesive components. The absorbable gelatine powders were applied dry to freely bleeding incisions made in the spleen of the pig.

*Experimental design*

The powder was applied to multiple surgical incisions in the spleen during the testing period. Comparative analysis of the recorded times were conducted and each test was repeated twice. The pigs were anaesthetised and not allowed to recover from anaesthesia.

*Sample preparation*

Depending on the extent of bleeding the incision area was treated with either a part or the whole content of a 1 g container of the powder. An amount of the powder adequate to obtain haemostasis was applied with a margin on all sides of about 10 mm.

*Surgical procedure*

The primary test parameter was to measure time to haemostasis.

A midline abdominal incision was made to expose the spleen. The size of the incisions was 1.5 cm long and 2 mm deep.

A total of 13 incisions were made in the pig spleen whereof one incision was used as a negative control to demonstrate a consistent bleeding with digital pressure and wetted gauze.

The test powder was applied as fast and deep as possible with a digital pressure for 2 minutes. Haemostasis evaluation was performed every 30 seconds, with an additional 30 seconds of digital pressure, until haemostasis was achieved for 30 seconds. The negative control using saline moistened gauze was performed at the start of the test to demonstrate consistent bleeding of more than 12 minutes in the absence of a haemostatic agent.

Pictures were taken for every 30 seconds documenting the procedure before, during and after to provide examples of handling characteristics of the tested haemostatics. Pictures of the negative control are taken until 12 minutes.

*Results*

The obtained results are presented in the below table. In addition, the obtained data are shown graphically in Fig. 7.

| Trial no. | Test powder | Haemostasis Time |
|---|---|---|
| 1 | Negative control (standard gauze and sterile saline) | > 12 min. |
| 2 | Gelatine powder from Example 2A | 4,5 min.[1] |
| 3 | Gelatine powder from Example 2A | 2 min. |
| 4 | Gelatine powder from Example 2B | 2 min. |
| 5 | Gelatine powder from Example 2B | 2,5 min. |
| 6 | Gelatine powder from Example 2A (glucose added) | 2 min.[1] |
| 7 | Gelatine powder from Example 2A (glucose added) | 5,5 min.[2] |
| 8 | Gelatine powder from Example 2B (glucose added) | 4 min. |
| 9 | Gelatine powder from Example 2B (glucose added) | 2,5 min. |
| 10 | Gelatine powder from Example 2A (sucrose added) | 3 min. |
| 11 | Gelatine powder from Example 2A (sucrose added) | 2,5 min. |
| 12 | Gelatine powder from Example 2B (sucrose added) | 2 min. |
| 13 | Gelatine powder from Example 2B (sucrose added) | 3,5 min.[3] |

[1] Only bleeding in the corner without powder

[2] Test article applied on bleeding spot without powder

[3] Powder applied on a very inclined surface and the powder ran off

The gelatine powder composition achieved haemostasis in an average time of 3.0 minutes compared to the negative control, which failed to achieve haemostasis within 12 minutes. There was however no difference between the test articles with or without the two different adhesive components.